Assessment of Indicator Parameters to Investigate the Seasonal Variation in Groundwater Quality of Chandrapur, Maharashtra, India

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Abstract

Groundwater quality of Chandrapur district was assessed in pre and post monsoon season based on the physicochemical parameters, biological parameters and water quality index. The water quality index was calculated using indicator parameters viz., pH, turbidity, temperature, nitrates, total phosphate, dissolved oxygen, biochemical oxygen demand, total solids, faecal coliforms with respect to its different uses like residential and commercial, as well as indicator parameters, in addition, index value was compared with quality rating to examine the seasonal variation in groundwater quality. The water quality index was observed from 74.0 to 83.0 and 63.0 to 78.0 in pre and post monsoon season, respectively. Our finding indicates that 100 percent (70 samples) groundwater samples were of desirable quality in pre monsoon season but 30 percent (21 samples) of all showed the quality change from well to less fair in post monsoon season, this seasonal variation in water quality rating has indicated the deterioration of water quality in the study area, thus indicating a need of proper treatment before use.

Keyword

Groundwater; Water Quality Index; Seasonal Variation; Physico-chemical Parameters; National Sanitation Foundation (NSF)

Introduction

Groundwater represents an important source of safe drinking water because surface water does not possess certain properties, but currently its quality is threatened by a combination of over-abstraction, microbiological and chemical contamination (Pedley and Howard 1997 and Reid et. al, 2003). The groundwater quality is a function of natural processes as well as anthropogenic activities. The safe potable water is enormously essential for living and groundwater is one of the sources for human consumption in both urban as well as rural areas. In India more than 80 percent of the rural population depends on untreated groundwater for potable water supplies (Sudhakar and Mamatha, 2004). The groundwater resources are at higher risk as its remediation is very difficult (Rajankar, et. al, 2010). In addition, the problem of drinking water contamination, water conservation and water quality management has tied much importance with sustainable development of countries, such as India. The major anthropogenic activities for continuous groundwater quality deterioration are urbanization, industrialization, and agriculture run off.

A study conducted by Central Ground Water Board in 2009 indicated that the groundwater quality was good and suitable for drinking and irrigation purpose, however, localized nitrate and fluoride contamination have been observed (GCWB, 2009). In the present study, the groundwater quality of Chandrapur district was studied by using biological and physico-chemical parameters, further Water Quality Index (WQI) was calculated using indicator parameters. This is first time that the WQI has been applied to groundwater of Chandrapur district.

Determination of water quality is very important for the suitability of water for various purposes. Use of WQI to determine the water quality of aqua resources is considered as one of the most effective tool to compare water resources (Sinha and Shrivastava, 1994; Pradhan et al., 2001). The WQI was developed in the

1970s by the Oregon Department of Environmental Quality for the purpose of summarizing and evaluating water quality trends and status (Dunnette, 1979).

The objectives behind the study were to develop an overall picture of the groundwater quality using WQI, assessment of seasonal variation in the groundwater quality, suitability of groundwater for different purposes, and contamination causes. The groundwater quality data were used to determine the overall quality of water within the district.

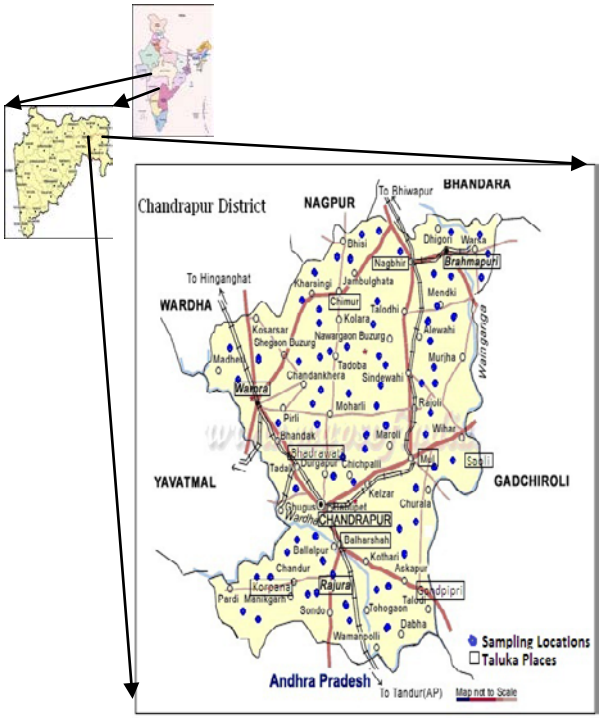

FIG. 1 LOCATION MAP OF GROUNDWATER SAMPLING AT CHANDRAPUR DISTRICT

Materials and Method

Study Area

Chandrapur formerly known as Chanda, a city situated in eastern Maharashtra state, Central India, covers a geographical area of 10,655 km, and is located in the eastern edge of Maharashtra in Nagpur division and forms the eastern part of 'Vidarbha' region between 19.30′ N and 20.45′ N latitude and 78.46′E longitude (FIG. 1) with average annual rainfall about 1420 mm, of which the eastern part receives more rainfall than west

Sampling

The sampling locations consist of rural as well as urban areas in this region. Seventy groundwater samples were collected from hand pump of 12 talukas viz., Ballarpur, Bhadrawati, Brahmapuri, Chandrapur, Chimur, Gondpipri, Korpana, Mul, Nagbhir, Rajura, Saoli and Warora during pre and post monsoon season of year 2006 to 2008. The samples collected in polythene containers of 2 liters capacity for physicochemical analysis after pumping out sufficient quantity of water from the source served as a representative sample. For bacteriological analysis, samples were collected in sterilized glass bottles of 500ml capacity then transported to the National Environmental Engineering Research Institute (NEERI), Nagpur laboratory under suitable condition for analysis as per standard procedure (APHA, 1998).

Analysis of groundwater samples

The groundwater samples were analyzed for physicochemical and biological parameters.

Physicochemical Analysis

The temperature of the samples was noted at themselves sampling point. Standard procedure involving spectrophotometry, flame photometry and volumetry were used for the physicochemical analysis (APHA, 1998).

Biological Analysis

The dissolved oxygen and biochemical oxygen demand were carried out using Winkler's method. In bacteriological examination, total coliforms (28^{0}C for 24 h) and fecal coliforms (44.5 ^{0}C for 24 h) were determined by Membrane Filtration (MF) technique, and the average values were recorded. The total coliforms (TC) was enumerated by M-Endo Agar, (Hi-Media Mumbai) which appeared as metallic sheen color colonies, and fecal coliforms (FC) were enumerated by M-FC Agar, (Hi-Media Mumbai) which appeared as blue color colonies.

Water Quality Index (WQI)

Water quality index was calculated using nine indicator parameters of water quality and the National Sanitation Foundation (NSF) WQI calculator. WQI, one of the most effective ways to communicate information on the quality of water to the concerned citizen and the policy makers, thus becomes an important parameter for the assessment and management of groundwater. WQI may be defined as a rating reflecting the composite influence of a number of water quality parameters on the overall quality of water. The main objective of the WQI is to turn complex water quality data into information

understandable and usable for the public. WQI based on some important parameters viz., pH, temperature, turbidity, nitrate, phosphate, total solids, dissolved oxygen, biochemical oxygen demand, and coliforms, which can provide simple indicator of water quality, gives a general idea of the possible problems with water in particular region (Bangalore and Sanjeev, 2008). NSF has given the classification of water quality on the basis of WQI rating presented in TABLE 1 (Rajankar, et. al, 2011).

TABLE 1 WATER QUALITY CRITERIA BASED ON WATER QUALITY INDEX RATING.

WQI Rating	Water Quality
0 to 25	Poor
25 to 50	Bad
50 to 70	Medium
70 to 90	Good
90 to 100	Excellent

Results and Discussion

The physicochemical and biological parameters have been subjected to statistical analysis and given in the TABLE 2 and TABLE 3, respectively. The observed ranges of the samples were compared with World Health Organization Standards (WHO). Further, the WQI was employed to calculate indicator parameters. The groundwater samples showed seasonal variation, which might happen due to different anthropogenic activities carried out near the sources.

Physicochemical Parameters

All the samples appeared colorless, clear and odorless. The observed pH values of all the samples were ranged from 7.3 to 8.5 and 6.9 to 8.5 in pre and post monsoon season respectively. In pre monsoon season, the lowest pH values were found at Ballarpur, Bhadrawati, and Chandrapur i.e. 7.3 and the highest pH value was found in another sample of Chandrapur taluka only i.e. 8.5, while in post monsoon season the lowest pH value was found at Bhadravati and the highest pH value was found at Chandrapur. In both seasons, pH values were within the limit. The turbidity was analyzed using turbidity meter and recorded in Nephelometric Turbidity Units (NTU). The observed turbidity in study area ranges from 0.95 NTU to 18.7 NTU and 1.9 NTU to 23.2 NTU in pre and post monsoon season respectively. Out of all 21 locations, the turbidity showed higher than permissible limit given by WHO (i.e., 5 NTU) in pre monsoon season and 45 locations showed the turbidity higher than permissible limit in post monsoon season. The highest turbidity in pre monsoon season and post monsoon season was observed in Chandrapur (18.7 NTU) and Bhadrawati (23.2 NTU) respectively, which indicates the water quality deterioration.

The temperature of the sample was between 26.6^{0}C to 30.2^{0}C and 25.7^{0}C to 30.9^{0}C in pre and post monsoon respectively. According to WHO standards (WHO, 1996), the acceptance limit for solids in groundwater is 500 mg/L, which may go up to 1500 mg/L in case of any alternative sources. In the present study, solids in ground water were found to be within the acceptance limit at all the sample location during pre monsoon season. It was further observed that solids in ground water were increased beyond the acceptable limit at 7 locations during post monsoon season which may be due to surface runoff. High solids level indicates water hardness in respective sampling station. It reduces the potability for drinking purposes in the region. The maximum solid was observed at Mul (604.8 mg/L).

The nitrate concentration was varied between 3.04 mg/L to 11.4 mg/L, 6.9 mg/L to 16.0 mg/L in pre and post monsoon season respectively and not a single location observed was above prescribed limit of 45 mg/L of WHO. Total phosphate concentration in pre and post monsoon season was varied from 0.01 mg/L to 0.4 mg/L and 0.02 and 1.58 mg/L in post monsoon season.

Biological Parameters

The dissolved oxygen of all the samples was varied from 2.2 mg/L to 5.4 mg/L in pre monsoon season and 2.0 mg/L and 5.2 mg/L in post monsoon season. The lowest observed dissolved oxygen may be due to percolation of drainage water containing organic waste, which depletes the oxygen level. The BOD of the groundwater samples ranged from 1.0 mg/L to 2.6 mg/L and 1.0 mg/L to 2.9 mg/L in pre and post monsoon season. The observed BOD was very low, indicating that there would not be much organic waste present in the water. The total coliforms were observed in 15 locations in pre monsoon season and 25 locations in post monsoon season, and the observed range of total coliforms was 0 to 48 CFU/100ml and 0 to 50 CFU/100ml in pre and post monsoon season, respectively. The highest total coliforms in pre monsoon was observed at Chandrapur (48 CFU/100 ml) and in post monsoon season at Saoli (50 CFU/100ml). The faecal coliforms were observed at 6 locations in pre monsoon season and 11 locations in post monsoon season, which may be attributed to surface runoff and percolation process, indicating that the bacteriological water in these areas was not safe and required treatment before drinking. The highest

faecal coliforms in pre monsoon was observed at Chandrapur (21 CFU/100 ml) and in post monsoon season at Saoli (11 CFU/100ml).

Water Quality Index (WQI)

The calculated WQI of the samples was presented in TABLE 2 varied from 74.0 to 83.0 and 63.0 to 78.0 in pre and post monsoon season, respectively (FIG. 2), which indicated that 100 percent (70 samples) groundwater samples were of good quality in pre monsoon season but 30 percent (21 samples) of all showed the quality changing from good to medium in post monsoon season, meaning the deterioration of water quality in the study area, thus a need of proper treatment before use was urgent.

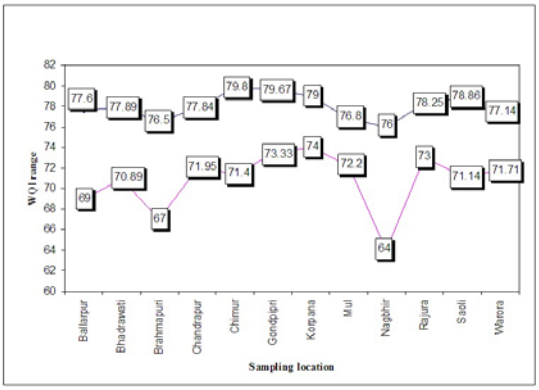

FIG. 2 SEASONAL VARIATION IN WATER QUALITY INDEX

(Upper value were recorded in pre monsoon season and lower values were recorded in post monsoon season)

Conclusions

In the present study, water quality index was developed for Chandrapur district. The WQI showed water quality change from good to medium in post monsoon season at three locations viz., Ballarpur, Brahmpuri and Nagbhir, which clearly indicated seasonal variation and deterioration in groundwater quality in the district, leading to health hazards to locals. Further studies are required to understand whether the deterioration in groundwater quality is temporary or a progressive phenomenon. This would help to prevent the irreparable damage to the overall groundwater system. Remediation measures should be adopted to restore the already contaminated groundwater sites.

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TABLE 2 PHYSICOCHEMICAL PARAMETERS IN PRE AND POST MONSOON SEASON SAMPLING LOCATIONS

SN	Sampling Location	Season	pH	Turbidity (NTU)	Temp (^{0}C)	Total Solids (mg/L)	NO_3 as N (mg/L)	Total Phosphate (mg/L)
1	Ballarpur	Pre	7.3-8.2 (7.74±0.43)	1.7-7.3 (4.40±2.46)	27.9-29.6 (28.58±0.64)	177.1-423 (307.14±89.22)	5.7-11.2 (7.92±2.44)	0.06-0.3 (0.12±0.10)
		Post	7.9-8.4 (8.18±0.26)	2-19.2 (8.86±7.00)	25.7-28.6 (27.60±1.15)	344.9-489.8 (405.66±66.39)	10.5-14 (11.86±1.37)	0.45-1.57 (0.75±0.46)
2	Bhadrawati	Pre	7.3-8.2 (7.73±0.32)	1.45-14 (4.99±3.91)	26.8-29 (28.16±0.63)	163.4-423 (293.56±75.46)	5.75-9.8 (8.18±1.46)	0.04-0.35 (0.12±0.11)
		Post	6.9-8.4 (7.94±0.53)	2.7-23.2 (11.67±7.05)	25.9-29.9 (27.71±1.29)	333.4-476 (391.58±56.10)	8.64-16 (11.28±2.07)	0.05-1.57 (0.54±0.46)
3	Brahmapuri	Pre	7.8-7.9 (7.85±0.07)	2.34-2.9 (2.62±0.40)	28.5-29.2 (28.85±0.49)	303-337.2 (320.10±24.18)	8.54-9.24 (8.89±0.49)	0.06-0.4 (0.23±0.24)
		Post	7.8-8.3 (8.05±0.35)	4.3-10.9 (7.60±4.67)	28.8-29.6 (29.20±0.57)	465.4-546 (505.70±56.99)	10.5-12.8 (11.65±1.63)	0.4-1.58 (0.99±0.83)
4	Chandrapur	Pre	7.3-8.5 (7.95±0.35)	1.7-18.7 (4.06±3.76)	26.6-30 (28.49±1.08)	132.6-440.1 (304.48±80.40)	3.04-10.8 (8.12±1.96)	0.03-0.32 (0.11±0.10)
		Post	7.3-8.5 (8.01±0.40)	2-12.2 (6.06±2.65)	25.8-30.9 (28.54±1.46)	244.4-526.1 (387.09±64.81)	9.8-12.8 (11.04±0.87)	0.07-1.09 (0.32±0.29)
5	Chimur	Pre	7.5-8.2 (7.88±0.29)	2.15-9 (4.78±2.56)	27.9-29.7 (28.72±0.70)	244.2-412.9 (309.44±70.04)	4.9-9.84 (7.31±2.20)	0.03-0.09 (0.05±0.02)
		Post	7.3-8.4 (7.94±0.47)	3.6-8.1 (5.88±1.90)	26.4-29.2 (27.38±1.09)	336.7-416.1 (370.62±38.11)	8.64-10.83 (10.07±0.89)	0.07-0.38 (0.15±0.13)
6	Gondpipri	Pre	7.8-8.4 (8.100.30)	3.3-4.05 (3.570.42)	28.2-29.4 (28.730.61)	221.7-322.8 (260.2354.67)	7.34-10.6 (9.381.78)	0.01-0.09 (0.040.05)
		Post	7.8-8.4 (8.17±0.32)	4.66-10.4 (7.19±2.93)	25.7-28.6 (27.07±1.46)	380.2-459.8 (409.47±43.78)	10.5-12.3 (11.24±0.94)	0.04-0.08 (0.06±0.02)
7	Korpana	Pre	7.5-8.4 (8.07±0.49)	2.93-6 (4.51±1.54)	27.5-28.5 (28.00±0.50)	213.6-331.9 (278.57±60.00)	6.7-8.9 (7.95±1.13)	0.01-0.04 (0.02±0.02)
		Post	7.9-8.4 (8.23±0.29)	5.4-8 (6.47±1.36)	25.9-29.4 (27.60±1.75)	331.8-390.7 (367.90±31.62)	10.7-12.34 (11.61±0.84)	0.12-0.33 (0.25±0.12)
8	Mul	Pre	7.7-8.2 (7.94±0.23)	0.95-7.6 (2.96±2.74)	28.2-29 (28.52±0.33)	282.2-434.7 (352.32±54.27)	7.31-10.9 (9.27±1.42)	0.04-0.17 (0.10±0.06)
		Post	7.5-8.4 (8.02±0.36)	3.2-9.7 (6.00±2.76)	26.4-29.4 (27.90±1.22)	379.5-604.8 (469.42±101.90)	10.69-16 (12.75±1.96)	0.03-0.31 (0.14±0.12)
9	Nagbhir	Pre	7.9	2.34	28.5	303	8.54	0.4
		Post	8.3	10.9	28.8	546	12.8	1.58
10	Rajura	Pre	7.5-8.3 (8.03±0.36)	1.45-12.8 (5.84±4.90)	27-28.6 (27.78±0.67)	282.8-390.2 (322.90±47.04)	5.76-8.24 (6.99±1.06)	0.04-0.06 (0.05±0.01)
		Post	7.3-8.2 (7.83±0.41)	3-12.6 (7.55±3.94)	27.5-29.6 (28.45±1.01)	349.4-551.2 (434.40±87.26)	6.9-10.98 (9.45±1.77)	0.06-1.31 (0.39±0.62)
11	Saoli	Pre	7.8-8.4 (8.00±0.23)	1.8-8.3 (4.04±2.51)	26.8-30 (28.69±1.15)	232.3-425.2 (310.81±70.36)	3.5-10.3 (7.81±2.56)	0.04-0.1 (0.07±0.02)
		Post	7.3-8.3 (7.86±0.33)	1.9-11.6 (5.97±3.60)	25.8-29.6 (27.93±1.18)	332.4-465.4 (400.04±44.13)	10-14 (10.93±1.38)	0.02-0.4 (0.17±0.13)
12	Warora	Pre	7.6-8.3 (8.06±0.28)	2.1-10.81 (6.03±3.18)	26.6-30.2 (28.89±1.14)	154.6-448 (300.33±108.85)	5.34-11.4 (8.57±1.86)	0.03-0.39 (0.14±0.16)
		Post	7.3-8.4 (7.81±0.42)	3.6-13 (7.46±3.04)	26.9-29.2 (27.66±0.83)	343.1-565.2 (436.19±68.65)	9.8-12.3 (10.84±0.87)	0.07-0.83 (0.30±0.34)
WHO Standards			7.0-8.5	5 NTU	-	500 mg/L	45 mg/L	-

Values are mentioned from minimum to maximum and brackets indicates average value and standard deviation

TABLE 3 BIOLOGICAL PARAMETERS INCLUDING WQI IN PRE AND POST MONSOON SEASON SAMPLING LOCATIONS

SN	Sampling Location	Season	Dissolved Oxygen (mg/L)	Biochemical Oxygen Demand (mg/L)	Total coliforms (CFU/100ml)	Faecal coliforms (CFU/100ml)	WQI
1	Ballarpur	Pre	3-3.8 (3.33±0.34)	1.0-2.1 (1.46±0.42)	0-9 (1.80±4.02)	0-0 (0.00±0.00)	75-82 (77.60±2.70)
		Post	3.5-4.3 (3.78±0.39)	1.1-2.3 (1.78±0.63)	0-29 (5.80±12.97)	0-9 (1.80±4.02)	67-71 (69.00±1.87)
2	Bhadrawati	Pre	2.6-5.3 (3.86±0.98)	1.1-2.6 (1.79±0.59)	0-28 (5.00±9.77)	0-3 (0.67±1.32)	75-81 (77.89±2.26)
		Post	2.8-4.7 (4.09±0.52)	1.4-2.9 (2.18±0.41)	0-43 (10.67±15.59)	0-2 (0.22±0.67)	68-75 (70.89±2.80)
3	Brahmapuri	Pre	2.4-3.8 (3.10±0.99)	1.2-1.9 (1.55±0.49)	0-0 (0.00±0.00)	0-0 (0.00±0.00)	76-77 (76.50±0.71)
		Post	2.2-4.1 (3.15±1.34)	1.1-2.3 (1.70±0.85)	0-9 (4.50±6.36)	0-0 (0.00±0.00)	64-70 (67.00±4.24)
4	Chandrapur	Pre	2.8-5.4 (3.83±0.90)	1.0-2.5 (1.79±0.53)	0-48 (4.11±11.04)	0-21 (1.11±4.82)	74-83 (77.84±2.81)
		Post	2-5.2 (3.38±0.94)	1.0-2.9 (1.98±0.66)	0-32 (8.58±11.17)	0-3 (0.37±0.90)	63-78 (71.95±3.66)
5	Chimur	Pre	2.5-5.4 (4.62±1.21)	1.2-2.6 (1.84±0.62)	0-22 (5.20±9.55)	0-4 (0.80±1.79)	77-82 (79.80±1.92)
		Post	2.3-4.2 (3.12±0.70)	1.0-2.9 (2.12±0.70)	0-37 (15.20±15.80)	0-2 (0.40±0.89)	63-75 (71.40±4.83)
6	Gondpipri	Pre	3.9-5.4 (4.530.78)	1.3-2.1 (1.670.40)	0-0 (0.000.00)	0-3 (1.001.73)	75-82 (79.67±4.04)
		Post	3.4-4.3 (3.77±0.47)	2.1-2.3 (2.23±0.12)	0-23 (14.00±12.29)	0-2 (1.00±1.00)	72-76 (73.33±2.31)
7	Korpana	Pre	3.9-4.6 (4.13±0.40)	1.2-2.5 (1.67±0.72)	0-0 (0.00±0.00)	0-0 (0.00±0.00)	77-80 (79.00±1.73)
		Post	2.8-4.6 (3.40±1.04)	1.2-2.4 (1.63±0.67)	0-29 (9.67±16.74)	0-0 (0.00±0.00)	72-77 (74.00±2.65)
8	Mul	Pre	2.4-5.4 (3.82±1.12)	1.7-2.5 (2.14±0.36)	0-19 (3.80±8.50)	0-1 (0.20±0.45)	75-80 (76.80±1.92)
		Post	2.8-5.2 (3.62±1.03)	1.1-2.9 (2.10±0.86)	0-28 (5.60±12.52)	0-5 (1.00±2.24)	69-78 (72.20±3.83)
9	Nagbhir	Pre	3.8	1.9	0	0	76
		Post	4.1	2.3	0	0	64
10	Rajura	Pre	3.3-4 (3.73±0.30)	1-2 (1.38±0.45)	0-0 (0.00±0.00)	0-0 (0.00±0.00)	75-81 (78.25±2.75)
		Post	2.9-4.6 (3.88±0.73)	1.0-2.3 (1.60±0.65)	0-12 (3.00±6.00)	0-0 (0.00±0.00)	69-78 (73.00±4.24)
11	Saoli	Pre	2.4-4.9 (3.84±0.80)	1.0-2.6 (1.60±0.64)	0-8 (1.86±3.29)	0-0 (0.00±0.00)	76-81 (78.86±1.77)
		Post	2.2-4 (3.13±0.67)	1.0-2.9 (1.74±0.90)	0-50 (12.57±21.75)	0-11 (2.14±4.18)	65-77 (71.14±3.93)
12	Warora	Pre	2.2-5.4 (4.17±1.08)	1.0-2.6 (1.90±0.60)	0-0 (0.00±0.00)	0-0 (0.00±0.00)	74-80 (77.14±2.12)
		Post	2.3-5.1 (3.43±0.88)	1.0-2.4 (1.89±0.62)	0-0 (0.00±0.00)	0-0 (0.00±0.00)	69-74 (71.71±1.60)
WHO Standards			5.0	6.0	0	0	WHO Standards not applicable for WQI

Values are mentioned from minimum to maximum and brackets indicates average value and standard deviation